Naval Postgraduate School
Monterey, California 93943-5138

NPS-09-02-027

SUMMARY OF RESEARCH 2001

Space Systems Academic Group

Graduate School of Engineering and Applied Sciences

Rudolf Panholzer
Chair

NAVAL POSTGRADUATE SCHOOL
Monterey, California

RADM David R. Ellison, USN
Superintendent

Richard Elster
Provost

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13. ABSTRACT (Maximum 200 words.)

This report contains project summaries of the research projects in the Space Systems Academic Group. A list of recent publications is also included, which consists of conference presentations and publications, books, contributions to books, published journal papers, and technical reports. Thesis abstracts of students advised by faculty in the Department are also included.

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THE NAVAL POSTGRADUATE SCHOOL MISSION

Increase the combat effectiveness of the U.S. and allied forces and enhance the security of the U.S.A. through advanced education and research programs focused on the technical, analytical, and managerial tools needed to confront defense related challenges of the future.

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PREFACE

Research at the Naval Postgraduate School is carried out by faculty in the four graduate schools (School of International Graduate Studies, Graduate School of Operations and Information Sciences, Graduate School of Engineering and Applied Sciences, and Graduate School of Business and Public Policy) and three Research Institutes (The Modeling, Virtual Environments, and Simulation (MOVES) Institute, Institute for Information Superiority and Innovation (I2SI), and Institute for Defense System Engineering and Analysis (IDSEA). This volume contains research summaries for the projects undertaken by faculty in the Space Systems Academic Group during 2001. The summary also contains thesis abstracts for those students advised by the Space Systems Academic Group faculty during 2001.

Questions about particular projects may be directed to the faculty Principal Investigator listed, the Department Chair, or the Department Associate Chair for Research. Questions may also be directed to the Office of the Associate Provost and Dean of Research. General questions about the Naval Postgraduate School Research Program should be directed to the Office of the Associate Provost and Dean of Research at (831) 656-2099 (voice) or research@nps.navy.mil (e-mail). Additional information is also available at the RESEARCH AT NPS website, http://web.nps.navy.mil/~code09/

Additional published information on the Naval Postgraduate School Research Program can be found in:

- *Compilation of Theses Abstracts:* A quarterly publication containing the abstracts of all unclassified theses by Naval Postgraduate School students.
- *Naval Postgraduate School Research*: A tri-annual (February, June, October) newsletter highlighting Naval Postgraduate School faculty and student research.
- *Summary of Research*: An annual publication containing research summaries for projects undertaken by the faculty of the Naval Postgraduate School.

This publication and those mentioned above can be found on-line at:
http://web.nps.navy.mil/~code09/publications.html.

INTRODUCTION

The research program at the Naval Postgraduate School exists to support the graduate education of our students. It does so by providing military relevant thesis topics that address issues from the current needs of the Fleet and Joint Forces to the science and technology that is required to sustain the long-term superiority of the Navy/DoD. It keeps our faculty current on Navy/DoD issues, and maintains the content of the upper division courses at the cutting edge of their disciplines. At the same time, the students and faculty together provide a very unique capability within the DoD for addressing warfighting problems. Our officers must be able to think innovatively and have the knowledge and skills that will let them apply technologies that are being rapidly developed in both the commercial and military sectors. Their unique knowledge of the operational Navy, when combined with a challenging thesis project that requires them to apply their focused graduate education, is one of the most effective methods for both solving Fleet problems and instilling the life-long capability for applying basic principles to the creative solution of complex problems.

The research program at the Naval Postgraduate School consists of both reimbursable (sponsored) and institutionally funded research. The research varies from very fundamental to very applied, from unclassified to all levels of classification.

- Reimbursable (Sponsored) Program: This program includes those projects externally funded on the basis of proposals submitted to outside sponsors by the School's faculty. These funds allow the faculty to interact closely with RDT&E program managers and high-level policymakers throughout the Navy, DoD, and other government agencies as well as with the private sector in defense-related technologies. The sponsored program utilizes Cooperative Research and Development Agreements (CRADAs) with private industry, participates in consortia with government laboratories and universities, provides off-campus courses either on-site at the recipient command, by VTC, or web-based, and provides short courses for technology updates.

- Naval Postgraduate School Institutionally Funded Research (NIFR) Program: The institutionally funded research program has several purposes: (1) to provide the initial support required for new faculty to establish a Navy/DoD relevant research area, (2) to provide support for major new initiatives that address near-term Fleet and OPNAV needs, (3) to enhance productive research that is reimbursably sponsored, and (4) to cost-share the support of a strong post-doctoral program.

In 2001, the level of research effort overall at the Naval Postgraduate School was 148 faculty work years and exceeded $48 million. The reimbursable program has grown steadily to provide the faculty and staff support that is required to sustain a strong and viable graduate school in times of reduced budgets. In FY2001, over 93% of the research program was externally supported. A profile of the sponsorship of the Naval Postgraduate School Research Program in FY2001 is provided in Figure 1.

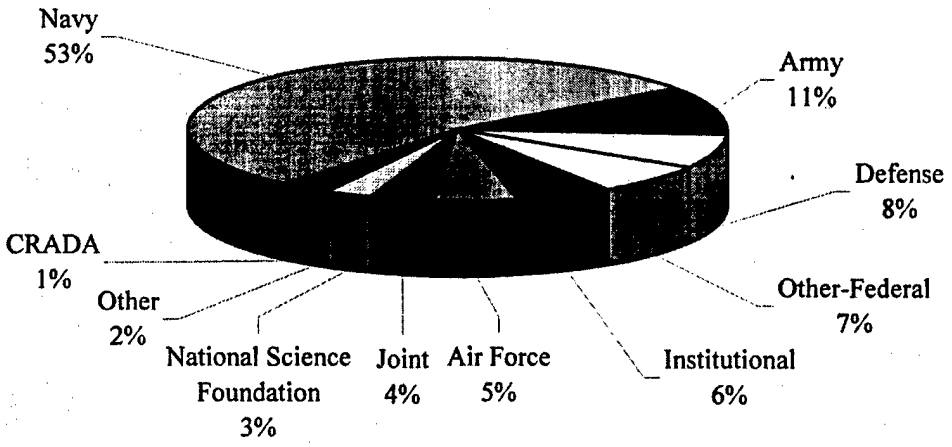


Figure 1. Profile of NPS Research and Sponsored Programs ($52M)

The Office of Naval Research is the largest Navy external sponsor. The Naval Postgraduate School also supports the Systems Commands, Warfare Centers, Navy Labs and other Navy agencies. A profile of external Navy sponsorship for FY2001 is provided in Figure 2.

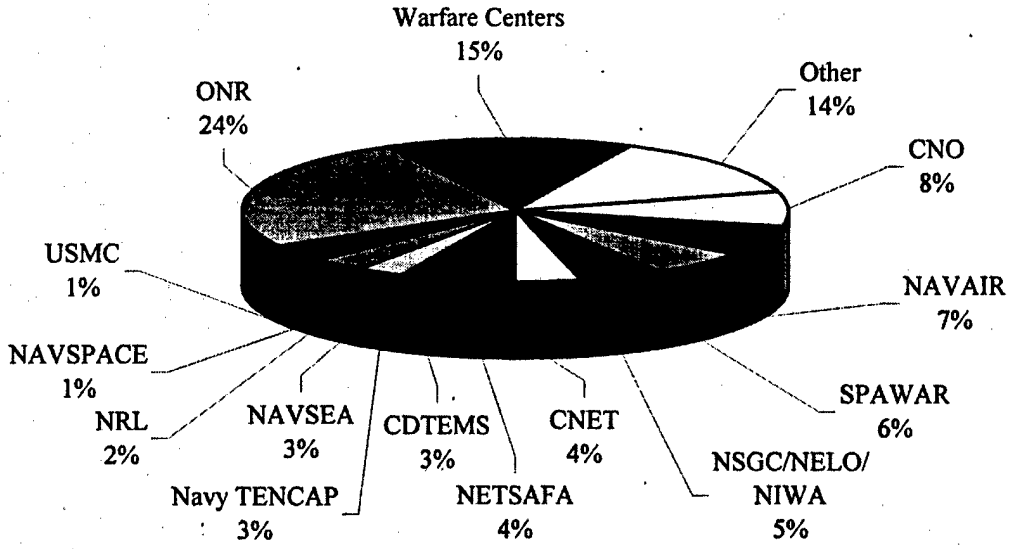


Figure 2. Navy External Sponsors of NPS Research and Sponsored Programs ($29M)

These are both challenging and exciting times at the Naval Postgraduate School and the research program exists to help ensure that we remain unique in our ability to provide education for the warfighter.

DAVID W. NETZER
Associate Provost and Dean of Research

September 2002

SPACE SYSTEMS ACADEMIC GROUP

RUDOLF PANHOLZER
CHAIR

DEPARTMENT SUMMARY

OVERVIEW:

The Space Systems Academic Group (SSAG) along with eight academic departments is an integral part of the Graduate School of Engineering and Applied Sciences. As an interdisciplinary association of professors it provides direction and guidance for two curricula: Space Systems Engineering and Space Systems Operations.

Officer students in the Space Systems curricula fulfill degree requirements for a Master of Science in the department of their choice or in a specialized Engineering Science. A space-oriented thesis is mandatory as well as course work to fulfill the requirements of a space billet. Officer graduates are prepared to manage the technical aspects of a space system life cycle including design, development, installation, and maintenance of spacecraft, space payloads, supporting ground stations, terminals, and C3 connectivity.

The SSAG serves as the focal point for all space-related research performed at NPS. A major goal is to couple NPS space research efforts with the graduate education of military officers. This is typically accomplished through space-related thesis research in several areas and includes small satellite projects created specifically as an educational tool for officer students. The SSAG oversees classified and unclassified student involvement in research activities and helps facilitate their placement in follow-on tours.

CURRICULA SERVED:

- Space Systems Operations
- Space Systems Engineering

DEGREES GRANTED:

- Master of Science in Space Systems Operations
- Master of Science in Astronautical Engineering
- Master of Science in Electrical Engineering
- Master of Science in Mechanical Engineering
- Master of Science in Applied Physics

RESEARCH THRUSTS:

- Military Applications for Space
- Space Reconnaissance and Remote Sensing
- Radiation Hardened Electronics for Space
- Design, Construction and Launching of Small Satellites
- Classified (SCI level) Research
- Satellite Communications Systems
- Military Space Systems and Architectures

RESEARCH CHAIRS:

- Navy Space Technology Program Chair
- Navy Tactical Exploration of National Capabilities (TENCAP) Space Chair
- Space Systems Academic Chair
- NASA Michael J. Smith Space Systems Chair
- National Reconnaissance Office Chair
- Lockheed Martin Space and Missile Operations Chair

RESEARCH CENTERS:

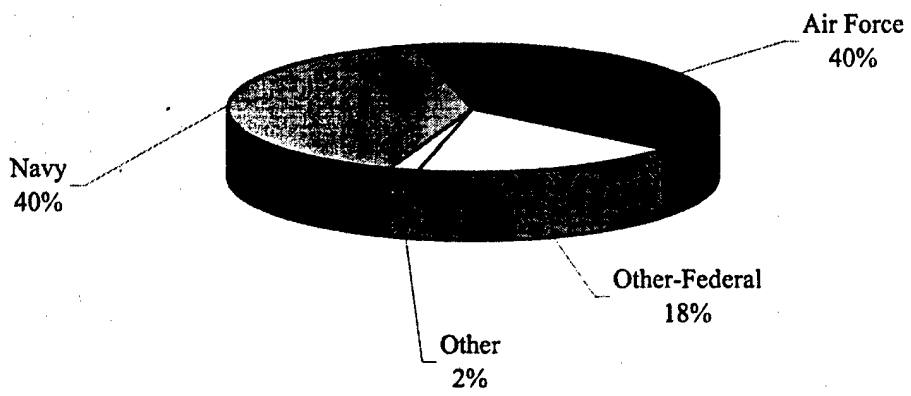
- Spacecraft Research and Design Center
- Center for Reconnaissance Research
- Center for Radiation Hardened Electronics
- Center for Cryptologic Research

RESEARCH FACILITIES:

- Open Site EMI/EMC Facility
- Satellite Ground Station Facility
- Space Warfare Computer Laboratory
- FLTSATCOM Satellite Operations
- Simulation and Test Laboratory
- Spacecraft Attitude Dynamics and Control Laboratory
- Spacecraft Environmental Simulation an Test Laboratory
- Radiation Effects Laboratory
- Solar Simulation Facility
- NPS-AFRL Optical Relay Spacecraft Laboratory
- Flash X-Ray Facility
- Electron Linear Accelerator
- Small Satellite Test and Development Laboratory
- Smart Structures Laboratory

RESEARCH PROGRAM (Research and Academic)-FY2001:

The Naval Postgraduate School's sponsored program exceeded $49 million in FY2001. Sponsored programs included both research and educational activities funded from an external source. A profile of the sponsored program for the Space Systems Academic Group is provided below:



Size of Program: $1059K

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FERROELECTRICITY NEWSLETTER

Rudolf Panholzer, Professor
Space Systems Academic Group
Sponsor: Office of Naval Research

OBJECTIVE: The objective of this quarterly publication is to provide the ferroelectric research community a means to keep informed about conferences, symposia, workshops and related activities in the field of integrated ferroelectrics. This newsletter offers summaries and titles of recently published and presented papers in addition to individual contributions by engineers and scientists in the field of ferroelectrics.

SUMMARY: A total of four Ferroelectricity Newsletters (FENL) were generated in hard copy format as well as made available on the web: http://www.sp.nps.navy.mil/projects/ferro/ferro.html

Input for the FENL was obtained from various sources, including open literature, proceedings of conferences, symposia, workshops and though individual contacts with scientists. In addition, the PI co-chaired the Thirteenth International Symposium on Integrated Ferroelectrics, a rich source of material for the FENL.

DoD KEY TECHNOLOGY AREAS: Materials, Processes and Structures

KEYWORDS: Integrated Ferroelectrics, Thin Films, Piezoelectric Materials, Pyroelectric Materials, Dielectric Properties, Non-volatile Memories

MAGNETIC TORQUE RODS FOR NAVAL POSTGRADUATE SCHOOL NPSat1

Rudolf Panholzer, Professor
Space Systems Academic Group
Sponsor: National Reconnaissance Office

OBJECTIVE: The objective of this proposal is to fund the acquisition of magnetic torque rods for the attitude control subsystem of the NPSat1 Micro-satellite which is part of the small satellite design program under the NPS Space Systems academic group.

SUMMARY: NPSAT1 will implement a novel, low-cost three-axis attitude control subsystem (ACS) which utilizes only magnetic torque rods for actuators, a three-axis magnetometer as a sensor input, and on-board orbit determination through software algorithms to achieve pointing accuracy less than ±5° in each axis. Funding under this proposal supports the acquisition of the flight magnetic torque rods for NPSat1.

DoD KEY TECHNOLOGY AREAS: Space Vehicles

KEYWORDS: Magnetic Torque Rods

NAVAL POSTGRADUATE SCHOOL SPACECRAFT ARCHITECTURE AND TECHNOLOGY DEMONSTRATION SATELLITE

Rudolf Panholzer, Professor
Space Systems Academic Group
Sponsor: National Reconnaissance Office

OBJECTIVE: The objective of this proposal is to fund the development of the NPSat1 Micro-satellite which is part of the small satellite design program under the NPS Space Systems Academic Group.

SUMMARY: NPSat1 supports the educational efforts in the Space Systems Academic Group while marrying research goals in small satellite technology development. NPSat1 is manifested on the Space Test Program (STP) MLV-05 mission due to launch in January 2006 on a Delta IV. A number of experiments will be flown from the National Reconnaissance Office, Naval Research Laboratory, and from

within the Naval Postgraduate School. Technology demonstration experiments aboard NPSat1 include on-orbit testing of triple-junction solar cells, micro-electromechanical systems (MEMS) rate sensors, lithium-ion and lithium-ion polymer batteries, ferroelectric memory, and a PC-compatible command and data handling architecture. Two science experiments onboard NPSat1 are provided by the Naval Research Laboratory: the coherent electromagnetic radio tomography (CERTO) beacon and a Langmuir probe.

DoD KEY TECHNOLOGY AREAS: Space Vehicles

KEYWORDS: Lithium-Ion Polymer Battery, Space Systems Engineering, Micro-satellite, Command and Data Handling, Ionospheric Tomography, Communications Networking

NAVAL SPACE SYSTEMS ACADEMIC CHAIR

Rudolf Panholzer, Professor
Charles M. Racoosin, Naval Space Systems Academic Chair
Space Systems Academic Group
Sponsor: Naval Space Command

OBJECTIVE: Incumbents of the Naval Space Systems academic chair engage in instruction and research and act as consultants in their area of specialization to students and faculty of the Naval Postgraduate School.

SUMMARY: This proposal funded the Naval Space Systems Academic Chair. The incumbent taught courses in Military Satellite Communications, Space Technology and Applications; Space Mission Analysis and Design; Space Mission Architecting; and Launch Systems selection. He acted as a thesis advisor for the following topics:

1) Using UAVs to supplement satellites for communications and signals intelligence missions,
2) Using UAVs as switching nodes for Battle Group intranets,
3) Joint Space Training,
4) Using Global Broadcast Service to deliver large meteorological products,
5) Using GPS more realistically in campaign-level simulations and wargames,
6) Using a wireless/satellite LAN/WAN in remote combat.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Air Vehicles, Space Vehicles, Command, Control and Communications, Computing and Software, Manpower, Personnel and Training, Sensors, Modeling and Simulation

KEYWORDS: Aerospace Propulsion, Air Vehicles, Space Vehicles, Communications, Computing, Software, Sensors, Modeling and Simulation

SPACE SYSTEMS OPERATIONS EXPERIENCE TOURS

Rudolf Panholzer, Professor
Space Systems Academic Group
Sponsor: Naval Space Command

OBJECTIVE: The objective of this proposal is to fund Space Systems Academic Group (SSAG) students thesis research projects, directed studies, and space operations experience tours.

SUMMARY: This proposal funded experience tour travel by the Space Systems Operations and Space Systems Engineering students to various government and commercial facilities and organizations. Sites visited this year were: NRO, DARPA, NRL, NRL Blossom Point, ADF Buckley AFB, Lockheed-Martin Littleton, Colorado, U.S. Space Command, Johnson Space Center, Kennedy Space Center, and AFTAC Patrick AFB.

Additionally, this proposal funded thesis specific travel such as: 1) to the ISIOC school in Colorado Springs, 2) a space power conference, 3) a blue force tracking/combat ID conference, 4) various trips to Washington D.C./NASA Dryden to visit thesis sponsors.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Space Vehicles, Command, Control and Communications, Computing and Software, Electronic Warfare, Manpower, Personnel and Training, Sensors, Manufacturing Science and Technology, Modeling and Simulation

KEYWORDS: Aerospace Propulsion, Air Vehicles, Space Vehicles, Communications, Computing and Software, Sensors, Modeling and Simulation

SPACE SYSTEMS STUDENTS THESIS RESEARCH PROJECTS, DIRECTED STUDIES, AND SPACE ENGINEERING EXPERIENCE TOUR

Rudolf Panholzer, Professor
Space Systems Academic Group
Sponsor: National Reconnaissance Office

OBJECTIVE: The objective of this proposal is to fund Space Systems Academic Group (SSAG) students thesis research projects, directed studies, and space engineering experience tours.

SUMMARY: Funding under this proposal directly supports the Space Systems Engineering curriculum. Specific areas of support include the engineering staff labor and the Space Systems Engineers experience tours. The engineering staff provides continuity and area expertise in the Small Satellite Design Studies Program as well as general thesis research support. The experience tour program includes six weeks of travel of which two weeks is in conjunction with officer students in the Space Systems Operations curriculum on a cadre tour of government, Department of Defense, and industry space facilities. Four weeks of the experience tour are set aside for off-site thesis research at a host facility.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Space Vehicles, Command, Control and Communications, Computing and Software, Electronic Warfare, Manpower, Personnel and Training, Sensors, Manufacturing Science and Technology, Modeling and Simulation

KEYWORDS: Aerospace Propulsion, Air Vehicles, Space Vehicles, Communications, Computing and Software, Sensors, Modeling and Simulation

FIRST PRINCIPLES PREDICTION OF X-RAY IMPULSE

Donald v. Wadsworth, Senior Lecturer
Space Systems Academic Group
Sponsor: Strategic Systems Programs Office

OBJECTIVE: Develop a first principle technique for predicting the impulse induced on selected surfaces by an X-ray burst in space. Validate the theoretical model by comparing predictions with available underground test data and other experimental data.

SUMMARY: This research project (currently in its second year) supports the Trident Stockpile-to-Target Stewardship program. The multi-year objectives are: (i) collect and archive key data (reports and interviews) relevant to predicting the vulnerability of an RB aeroshell to an x-ray burst in space, (ii) compare the capability of existing physics-based models (finite-element hydro codes and radiation deposition codes) to predict blow-off impulse and damage to various RB composite materials, (iii) modify a selected code to improve fidelity, (iv) validate the modified code against existing test data (UGT and AGT) and, if needed, plan and execute new tests using existing facilities (flash x-ray and surface loading). This is a collaborative effort involving faculty in the NPS Space Systems Academic Group and the departments of Physics, Mechanical Engineering, and Electrical and Computer Engineering. Two Navy

master's degree candidates are performing thesis research in support of this effort. Significant consulting support is being provided by the DoE National Laboratories, as well as Defense Threat Reduction Agency, and DoD contractors.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Directed Energy Weapons

KEYWORDS: X-ray, Weapons Effects, Nuclear Weapon

SPACE SYSTEMS ACADEMIC GROUP

2001 Faculty Publications and Presentations

PUBLICATIONS/PRESENTATIONS

There are no publications included in the Space Systems Academic Group section. Publications for professors associated with Space Systems are listed in each professor's home department.

SPACE SYSTEMS ACADEMIC GROUP

Thesis Abstracts

CONCEPTUAL DESIGN TOOLS FOR THE NPS SPACECRAFT DESIGN CENTER

Michael N. Abreu-Lieutenant, United States Navy
B.S., United States Naval Academy, 1992
Master of Science in Astronautical Engineering-September 2001
Advisor: Brij N. Agrawal, Department of Aeronautics and Astronautics
Second Reader: Joseph Aguilar, Aerospace Corporation
Christopher Taylor, Aerospace Corporation

The thesis surveys and develops spacecraft design techniques and tools involving the integration of collaborative/concurrent engineering (CE) for spacecraft design, specifically in the areas of spreadsheet and CAD/CAE software, for the NPS Spacecraft Design Center (SDC). The applicability of solid modeling to the spacecraft design process is also explored. A previous class design is modeled using a solid modeling tool and the results compared against the time and effort required for the original. In addition, two CE software tools obtained from commercial and university sources are installed in the SDC, improved, documented if necessary, and evaluated. The capabilities are evaluated with regard to learning curve, CE and their utility to the curriculum. A User's Guide for one of the software tools is written, as no documentation existed for it prior to this thesis. In addition, procedures for spacecraft design utilizing the SDC are developed in order to enhance student design capabilities and further their educational experience.

DoD KEY TECHNOLOGY AREAS: Space Vehicles

KEYWORDS: Spacecraft Design

TERRAIN CATEGORIZATION USING MULTITEMPORAL INFRARED IMAGERY

Julie M. Alfieri-Lieutenant, United States Navy
B.S., United States Naval Academy, 1996
Masters of Science in Systems Technology-June 2001
Advisor: Richard C. Olsen, Department of Physics
Second Reader: Alan A. Ross, Navy Tactical Exploitation of National Capabilities (TENCAP) Chair Professor

Terrain Categorization (TERCAT) in remote sensing is used extensively by the United States Military to conduct Intelligence Preparation of the Battlefield (IPB). This thesis explores the feasibility of exploiting multitemporal infrared imagery for the purpose of TERCAT. Two littoral locations were imaged multiple times from August through October 1998 using National Technical Means (NTM). Images were merged and analyzed using commercial off the shelf (COTS) technology, producing TERCAT maps of both target areas. Both supervised and unsupervised classification methods were used in this process. The TERCAT maps were compared with ground truth measurements to determine the overall classification accuracy. Accuracy levels above eighty percent were achieved. This variation on traditional change detection methods provides an alternative single-sensor approach to terrain categorization that can be utilized by the military.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Remote Sensing, Sensor Fusion, TERCAT

PERFORMANCE AND SPACE BORNE APPLICATION ANALYSIS OF THE HIGHER ORDER CYCLOSTATIONARY BASED CLASSIFIER

Brian K. Bailey-Captain, United States Air Force
B.S., Carnegie Mellon University, 1994
Master of Science in Astronautical Engineering-December 2000
Advisors: Brij N. Agrawal, Department of Aeronautics and Astronautics
Charles W. Therrien, Department of Electrical and Computer Engineering
Second Reader: Tri T. Ha, Department of Electrical and Computer Engineering

Testing of the Higher Order Cyclostationary Based Classifier (HBC) is conducted to evaluate system operational performance. Utilizing Higher Order Cyclostationary (HOCS) analysis techniques, the HBC is designed to automatically detect and classify communication and radar signals contained in input signal samples. While test results utilizing earlier data were inconclusive on the effectiveness of the system, a more rigorous testing for Binary Phase-Shift Keying (BPSK) modulation scheme is herein carried out. The results of the HBC analysis reveal a system which experiences difficulty in performing modulation detection and classification of the input data at signal-to-noise ratios above 10 dB. The HBC automatic band-of-interest detector also shows evidence of interfering with accurate signal classification results. Recommended improvements to the algorithms and interface are presented to address these and other observed trends. An application of the HBC system to the Naval Research Laboratory's Pre-Configured Interface Payload (PCIP) program are assessed for space borne testing of the HBC system.

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Computing and Software, Sensors, Modeling and Simulation

KEYWORDS: Cyclostationary, Cyclostationarity, Digital Signals, Signal Classification, Signals Intelligence (SIGINT), Spacecraft Payload Integration, Pre-Configured Interface Payload (PCIP)
work in this Mach number test spectrum.

QUANTIFYING THE EFFECT OF CRYPTOLOGY AS A DECISION MAKING TOOL FOR THE NAVAL WARFIGHTER

Oswaldo Cornejo-Lieutenant, United States Navy
B.S., Kansas State University, 1994
Master of Science in Space Systems Operations-September 2001
Advisors: Herschel H. Loomis, Jr., Department of Electrical and Computer Engineering
John W. Van Hise, Jr., Department of Electrical and Computer Engineering

This abstract is classified.

DoD KEY TECHNOLOGY AREAS: Not available.

KEYWORDS: Not available.

FEASIBILITY ANALYSIS AND DESIGN OF A FAULT TOLERANT COMPUTING SYSTEM: A TMR MICROPROCESSOR SYSTEM DESIGN OF 64-BIT COTS MICROPROCESSORS

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B.S., Turkish Naval Academy, 1995
Master of Science in Electrical Engineering-March 2001
Advisors: Alan A. Ross, Navy Tactical Exploitation of National Capabilities (TENCAP) Chair
Herschel H. Loomis, Department of Electrical and Computer Engineering

The purpose of this thesis is to analyze and determine the feasibility of implementing a fault tolerant computing system that is able to function in the presence of radiation induced Single Event Upsets (SEU) by using the Triple Modular Redundancy (TMR) technique with 64-bit Commercial-off-the-Shelf (COTS) microprocessors.

Due to the radiation environment in space, electronic devices must be designed to tolerate the radiation effects. While there are radiation-hardened devices that can tolerate radiation effects, they offer lower performance and higher cost than COTS devices. On the other hand, COTS devices offer lower cost, orders of magnitude higher performance, shorter design time and better software availability and compatibility. However, COTS devices are susceptible to the radiation effects. In order to use COTS devices in space environment, a fault tolerance technique such as TMR needs to be implemented.

This thesis presents the design and analysis of a TMR 64-bit COTS microprocessor implementation. The system incorporates three 64-bit microprocessors, the memory system including SRAM and PROM memory modules and the programmable logic devices that are used to implement the TMR technique. The validity of the design is verified by the timing analysis conducted on read and write operations.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Electronics

KEYWORDS: Fault Tolerant Computing, Triple Modular Redundancy (TMR), Commercial-off-the-Shelf (COTS) Devices, Single Event Upsets (SEU)

A PATHFINDER FOR A MULTI-INT INFORMATION ARCHITECTURE

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Today's intelligence data management systems are not scalable and flexible enough to meet 21st century warfighter requirements. There is little or no information sharing between the producers of intelligence, perpetuating them as islands (stovepipes) of information. Web technologies offer an improvement over existing intelligence information management systems by providing loosely-coupled connectivity through the use of hypertext transfer protocol (HTTP) and markup language (HTML). But web-based implementations still fall far short of satisfying the majority of requirements posed by intelligence community users. What is needed is a flexible distributed architecture that leverages existing assets and the benefits of web technologies, while providing needed improvements that better address the need for multi-intelligence interoperability.

This thesis applies a systematic requirement-driven approach to define a pathfinder for a multi-intelligence information architecture. The pathfinder concept is discussed as a necessary acquisition tool to help bound and scale a realistic solution. Key enabling information technologies are evaluated and recommended as a foundation for implementation. A case study is presented to show proof-of-concept and progress toward achieving a multi-intelligence information architecture.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Human Systems Interface, Other (Information Technology)

KEYWORDS: Enterprise Computing, Object-Oriented Systems, Distributed Processing, Common Object Request Broker Architecture (CORBA), Java, Extensible Markup Language (XML), Object Databases, Ontology

A NAVAL SPECIAL WARFARE CONCEPT OF OPERATIONS FOR THE MOBILE EXPLORATION SYSTEM (MEX) IN A NETWORK CENTRIC ENVIRONMENT

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The development of wireless local area networks (WLANs) has greatly accelerated the commercial development of wireless technology for enterprise network solutions. Government and military organizations are also benefiting from the competition and interoperability fostered by the new marketplace. Given the decreasing cost, and increasing capabilities of WLANs, military units could soon adopt commercial WLANs as the networks of choice for combat operations. This trend will facilitate the realization of Network Centric Operations (NCO).

Wireless technology availability, coupled with the U.S. military's trend of looking to commercial-off-the-shelf (COTS) communication and computing solutions, necessitate an awareness of the characteristics of WLANs. The capabilities of the WLAN technology will influence the Concept of Operations (CONOPS).

This thesis researches and conducts an analysis of a mobile WLAN at the NASA Ames Research Center in Moffett Field, California, called the Mobile Exploration System (MEX), developed as a test bed for future planetary exploration concepts. This thesis determines the types of WLAN technologies that could be implemented in Naval Special Warfare (NSW) operations in a network centric context and proposes a CONOPS. Finally, the thesis provides a cost-benefit framework for analyzing the application of WLAN technologies to NSW mission areas.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Wireless Local Area Network, Network Centric Operations, Planetary Exploration Concepts, CONOPS

HIGH ALTITUDE LONG ENDURANCE (HALE) PLATFORMS FOR TACTICAL WIRELESS COMMUNICATIONS AND SENSOR USE IN MILITARY OPERATIONS

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United States military forces are transitioning to network centric operations, as described in Joint Vision 2010 and Joint Vision 2020. Warfighting elements will function as individual nodes in a global information grid with an end-to-end infrastructure that provides information on demand to warfighters, policymakers, and support personnel. This transition will place additional demands on wireless communications and Intelligence, Surveillance, and Reconnaissance (ISR) systems. However, current and planned space-based communications solutions are costly and have significant shortfalls. Likewise, ISR systems will have difficulty fulfilling near real-time requirements and sensor-to-shooter roles. One possible solution is through the use of emerging stratospheric platforms. In the area of communications and ISR support, this thesis; reviews the Services' doctrines and future warfighting needs, identifies available space-based systems along with their shortfalls, and defines support capabilities from the stratospheric environment. It then provides an in-depth review of emerging high altitude long endurance (HALE) platforms, analyzes HALE platforms survivability, provides a concept of operations (CONOPS) for HALE employment, and performs a HALE platform comparative analysis.

DoD KEY TECHNOLOGY AREAS: Sensors

KEYWORDS: Wireless Communications, Network Centric Operations, ISR, High Altitude Long Endurance Platforms, HALE, CONOPS

A NUMERICAL STUDY OF FUEL-OPTIMAL LOW-EARTH-ORBIT MAINTENANCE

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This thesis studies the fuel optimal periodic reboost profile required to maintain a spacecraft experiencing drag in low-earth-orbit (LEO). Recent advances in computational optimal control theory are employed, along with a Legendre-Gauss-Lobatto Pseudospectral collocation code developed at the Naval Postgraduate School, to solve the problem. Solutions obtained by this method are compared against a previous study. Key issues were checking the optimality of the solutions by way of the necessary conditions and the behavior of the solution to changes in the thruster size. The results confirmed Jensen's findings of propellant savings of one to five percent when compared against a middle altitude Forced Keplerian Trajectory (FKT). Larger savings are predicted if compared against a finite-burn Hohmann transfer with drag. The costates estimates compared favorable against necessary conditions of Pontryagin's Minimum Principle. Analysis of the switching function yielded periods of thrust-modulated arcs. The optimal thrust profile appears to be a thrust-modulated burn to raise the orbit followed by an orbital decay and a terminating thrust-modulated arc. For a sufficiently low thrust-control authority, the switching structure includes a maximum thrust arc. Indirect optimization techniques to confirm these findings were unsuccessful.

DoD KEY TECHNOLOGY AREA: Space Vehicles

KEYWORDS: Orbital Mechanics, Optimization, Optimal Control Theory, Orbit Maintenance

TELEMETRY SYSTEMS ANALYSIS AND DESIGN

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The Navy has a valuable opportunity to improve its own products and operations efficiency by showing its future leaders and designers how to design effective and viable telemetry, tracking, and commanding (TT&C) systems, and their operation. One system is the FLTSAT military communications constellation of spacecraft, one of which has been a static display at the Naval Postgraduate School (NPS) until June, 2000. The primary objective was to make this spacecraft operational and thus provide a new operational spacecraft laboratory for other NPS students. This thesis may also be used as a primer for the space engineering or space operations student regarding TT&C systems design. Great effort has been taken to document and discuss current design practices and standards adopted by DoD laboratories, test facilities, and operation centers. A TT&C system designed for a spacecraft incorporating all the traditional subsystems (payload, thermal, structural, power, TT&C, attitude control) is included.

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Other (Communications)

KEYWORDS: Space Vehicles, Communications

MICROELECTROMECHANICAL SYSTEMS FOR SMALL SATELLITE APPLICATIONS

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Microelectromechanical systems (MEMS) have been developing for the past few decades, but recent spaceflight demonstrations have highlighted the potential of this technology as an attractive paradigm shift in how aerospace systems should be developed, maintained and used as the dawn of a new space age emerges. MEMS will generate a revolution in the way people see and control tomorrow's satellites by combining technological advances in sensors, actuators, reactionary systems, spacecraft attitude control systems, information processing and storage with the miniaturization of these components. MEMS will enable the realization of decentralizing satellites and, therefore, create a paradigm shift in the conceptual operation and development process of how people think about using satellites. The vision of what can be achieved from space is no longer bound by what an individual satellite can accomplish, rather, a number of much smaller cooperating satellites can share the functionality at a lower cost in development and production. This thesis will validate the concept of MEMS and its applicability to space and conclude by examining possible paths that the Naval Postgraduate School microsatellite, NPSAT1, can take to reducing subsystem mass and power through the use of MEMS components.

DoD KEY TECHNOLOGY AREA: Sensors, Other (Microelectromechanical Systems)

KEYWORDS: Micromlectromechanical Systems, MEMS, Nanosatellites, Microsatellites, NPSAT1, Gyroscopes

ANGULAR RATE ESTIMATION FOR MULTI-BODY SPACECRAFT ATTITUDE CONTROL

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Spacecraft with high performance attitude control systems requirements have traditionally relied on imperfect mechanical gyroscopes for primary attitude determination. Gyro bias errors are connected with a Kalman filter algorithm that uses updates from precise attitude sensors like star trackers. Gyroscopes, however, have a tendency to degrade or fail on orbit, becoming a life-limiting factor for many satellites. When errors become erratic, pointing accuracy may be lost during short star gaps. Unpredictable gyros degradations have impacted NASA spacecraft missions such as Skylab and Hubble Space Telescope as several DoD and ESA satellites. An alternative source of angular rate information is a software implemented real tie dynamic model. Inputs to the model from internal sensors and known spacecraft parameters enable the tracking of total systemangular momentum from which body rates can be determined. With this technique, the Kalman filter algorithm provides error corrections to the dynamic model. The accuracy of internal sensor and input parameters determine the effectivenes of this angular rate estimation technique. This thesis presents the background for understanding and implementation of the technique into a representative attitude determination system. The system is incorporated into an attitude simulation model developed in SIMULINK to evaluate the effects of dynamic modeling errors and sensor inaccuracies. Results are presented that indicate that real time dynamic modeling is an effective method of angular rate determination for maneuvering multi-body spacecraft attitude control systems.

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Modeling and Simulation

KEYWORDS: Dynamic Gyro, Kalman Filter, Attitude Determination, Rate Estimation, Star Trackers, Attitude Simulation, Multi-body Dynamics, Quaternion, MATLAB, SIMULINK

TERRAIN CATGORIZATION USING MULTITEMPORAL SYNTHETIC APERATURE RADAR (SAR)

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Multitemporal synthetic aperture radar (SAR) imagery is exploited for the purpose of Terrain Categorization (TERCAT). This thesis explores using SAR data from National Technical Means (NTM) to construct detailed TERCAT maps. Two littoral military locations were imaged multiple times over a three-month period. These images were registered to each other and combined to form multi-band composite images. Unsupervised and supervised classification techniques were then used to construct TERCAT maps of the two littoral military locations. The unsupervised and supervised classification techniques used unique spectral elements in the multi-band composite images to assign each pixel in the composite images to a terrain class. The TERCAT maps were compared with ground truth measurements to determine the overall categorization accuracy with good results. The military utility of the TERCAT techniques and products was explored with an emphasis on the intelligence value.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Remote Sensing; Sensor Fusion, TERCAT

PROJECT OVERVIEW OF THE NAVAL POSTGRADUATE SCHOOL SPACECRAFT ARCHITECTURE AND TECHNOLOGY DEMONSTRATION EXPERIMENT

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The Naval Postgraduate School's current attempt at getting another spacecraft into orbit is focusing on Naval Postgraduate School Spacecraft Architecture and Technology Demonstration Experiment (NPSAT1). Building on lessons learned from PANSAT, in addition to targeting incremental improvements and advances in multiple areas of spacecraft design, NPSAT1 is being built as a three-axis stabilized platform. It will be using commercial-off-the-shelf (COTS) components in many of its subsystems to provide some testing and experimentation on how certain COTS components can handle space environments and the challenges this unique environment presents. Other characteristics of NPSAT1 include a PC-compatible Command and Data Handling (C&DH) subsystem, lithium-ion polymer batteries, a Linux operating system, and Ferroelectric RAM.

NPS possesses a unique ability to educate a large number of service personnel in a wide variety of space-related topics. In particular, NPS is not only able to provide classroom and laboratory education on principles, concepts, philosophies, and historical perspectives of space, but also it can provide the student the opportunity to conduct on-orbit operations and testing of the same spacecraft that were designed and built on the grounds of the NPS campus. This thesis describes the overall NPSAT1 design project, including descriptions of the five experiments onboard, and many of the associated requirements that ultimately lead to a successful mission on orbit.

DoD KEY TECHNOLOGY AREAS: Space Vehicles

KEYWORDS: NPSAT1, Spacecraft Design, Spacecraft Architecture

MODELING THE EFFECTS OF GPS JAMMING ON A THEATER CAMPAIGN

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This study reviews the manner in which four precision-guided weapons utilize the NAVSTAR Global Positioning System (GPS) to increase their accuracy, and threats to GPS that may be employed to reduce their accuracy. The study incorporates a Navy-approved Modeling and Simulation (M&S) program to modify weapons parameters affected by GPS. The M&S system is used to simulate a large-scale theater campaign, based upon actual war plans. The results of the simulation scenario are used to evaluate possible threats to GPS guided weapons and to highlight thought processes that military planners may need to consider when operating in a GPS-denied or GPS-degraded electronic warfare environment.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare

KEYWORDS: NAVSTAR GPS, GPS Guided Weapons

EXPLOITATION OF NATIONAL SENSORS FOR TERRAIN CATEGORIZATION (U)

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Abstract is classified.

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Sensors, Other (Intelligence, Indications and Warning (I&W))

KEYWORDS: Sensor Fusion, Multispectral Imaging, Imagery Intelligence, TERCAT

SIMULATION OF GUIDED AEROASSISTED MANEUVERS FOR PLANETARY MISSIONS

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Aeroassisted maneuvers are distinguished from purely propulsive maneuvers in that aerodynamic forces are used to assist in orbital maneuvers of spacecraft. These types of maneuvers can vary from aerocapture to direct entry. The NASA Solar System Exploration Program lays the foundation for the future of interplanetary exploration using various versions of these aeroassisted maneuvers. The computer program ACAPS, designed at the Naval Postgraduate School, was developed for the Jet Propulsion Laboratory (JPL) to conduct high-level mission design for exploration missions to Mars. The primary research objective of this thesis was to upgrade the previous version of ACAPS, to produce a tool that provides new capabilities in support of the Solar System Exploration Program. The secondary research objective of this thesis was to provide direct support to JPL mission planners. The first major upgrade was the incorporation

of additional planets which allows for simulation at Venus, Saturn, Neptune, and Titan. The second focus of work was the incorporation of guidance to include ballute guidance and the Apollo derived Mars Precision Lander guidance algorithm. This thesis also documents how these upgrades were used to support future missions to Venus, Neptune, Saturn and Titan; particularly in the possibilities of using ballutes.

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Modeling and Simulation

KEYWORDS: Aerocapture Simulation (ACAPS), Aeroassist, National Aeronautics and Space Administration (NASA), Jet Propulsion Laboratory (JPL), Mars Sample Return (MSR) Mission, Mars Micromission, MATLAB, SIMULINK, Ballute, Parachute

SPACE TRAINING AND EDUCATION FOR USN CRYPTOLOGIC OFFICERS - THE ROAD TO SPACE CERTIFICATION

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This thesis discusses the importance of space-related education and training for Naval cryptologic officers in their efforts to support the warfighter. It includes a discussion of the learning continuum concept, an outline of cryptologic officer's career milestones for space-related training, and a discussion of the Navy's Distributed Learning initiatives. This thesis provides a framework for the establishment of a Space Certification Program for Naval cryptologists. The proposed Space Certification model was designed to allow expansion of the program to include Naval officers in other communities.

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel and Training

KEYWORDS: Space Certification Process, Learning Continuum Concept, Cryptologic Officers

A COMPUTATIONALLY EFFICIENT ALGORITHM FOR DISTURBANCE CANCELLATION TO MEET THE REQUIREMENTS FOR OPTICAL PAYLOADS IN SATELLITES

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Vibration control is a very important issue in satellites. The new high-resolution digital imaging devices are especially sensitive to vibrations. Antennas used in laser communications also require a very quiet environment so that their performance is not degraded. The Stewart platform is capable of isolating an optical payload from the noisy spacecraft bus. Until recently, only passive methods were used in all vibration isolation applications. Recent advances in Digital Signal Processing techniques made the development of vibration control algorithms possible, but these usually require large computational power. This work explores using a computationally efficient vibration-isolation method for optical payloads by using hexapods. The method suppresses the vibration at the assigned frequencies and does not affect unassigned frequencies if the plant is linear.

The mathematical analysis includes convergence analysis and the effect of unassigned frequencies in the output. The computational requirements of the algorithm is evaluated and is compared to the Multiple-Error Least Mean Square. The method is very robust to nonlinearities; its performance is comparable to the Multiple-Error Least Mean Square with a fraction of the computational time and memory requirements. It also requires very little plant knowledge. Theoretical results are verified through simulations using a Single-Input/Single-Output plant and a nonlinear hexapod model. The controller was also experimentally

validated in two different hexapods and the performance was found to be similar to or better than the performance obtained with the Multiple-Error Least Mean Square method when a noisy reference signal is used.

DoD KEY TECHNOLOGY AREAS: Space Vehicles

KEYWORDS: Vibration Control, Vibration-Isolation Method, Optical Payloads

REMOTE NANOSATELLITE FORMATION DESIGNS WITH ORBIT PERTURBATION CORRECTIONS AND ATTITUDE CONTROL/PROPULSION SUBSYSTEM CORRELATION

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The innovative idea of distributing the functionality of current larger satellites among smaller, cooperative satellites has been sincerely considered for assorted space missions to accomplish goals that are not possible or very difficult to do with a single satellite. Additionally, the utilization of smaller satellites is maximized within formations and clusters to conduct missions such as interferometry and earth-sensing. This paper presents a methodology to describe, populate and analyze numerous formation designs employing the use of Hill's equations of motion to describe a formation's dynamics. These equations of motion are then programmed into a MATLAB code to produce Cartesian elements for input into a Satellite Tool Kit((STK) simulation that demonstrates numerous possible cluster formation designs. These simulations are then used to determine ?V requirements for overcoming LEO-type perturbations that were modeled within STK's High Precision Orbit Propagator (HPOP).

Finally, components from two subsystems [Attitude Determination and Control (ADCS) and Propulsion], using the ?V calculations from the simulation analysis and current advances in MicroElectroMechanical systems (MEMs) and nanosatellite technology, are presented based on a mass constraint of 10kg for the entire satellite.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion, Space Vehicles, Modeling and Simulation

KEYWORDS: Satellite Formation, Orbit Dynamics, STK, Nanosatellite, and Satellite Propulsion

EVALUATION OF SURVEILLANCE RECONNAISSANCE MANAGEMENT TOOL AND UTILITY/FUNCTIONALITY TO FUTURE SURFACE COMBATANTS

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Alan Ross, Navy Tactical Exploitation of National Capabilities Chair
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This abstract is classified.

DoD KEY TECHNOLOGY AREAS: Not available.

KEYWORDS: Not available.

WORLDWIDE METEOROLOGICAL AND OCEANOGRAPHIC DATA DISTRIBUTION USING THE GLOBAL BROADCAST SERVICE

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The Fleet Numerical Meteorology and Oceanography Center (FNMOC) produces large meteorological and oceanographic (METOC) data files in support of regional METOC centers worldwide. These data files can be from 50 megabytes to 1 gigabyte in size and can take up to one hour and twenty-eight minutes to send across a T-1 (1.544 Megabits per second (Mbps)) line due to physical limitations and network delays. However, not all of FNMOC's customers have access to a T-1 line. For example, the Naval European METOC Center (NEMOC) in Rota, Spain is hampered by an inadequate telecommunications infrastructure compared to Continental United States (CONUS) standards. This thesis addresses the operational feasibility of using the Global Broadcast Service (GBS), a global system of satellites providing a high speed broadcast service of video and data, for transferring large METOC data products from FNMOC to METOC regional centers around the world.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Command, Control and Communications, Computing and Software

KEYWORDS: Global Broadcast Service, GBS, Satellite Communications, Bandwidth, Meteorology, Oceanography, Fleet Numerical Meteorological and Oceanography Center, FNMOC, Joint C4I, C4I, C3, Joint Command, Control, Communications, Computers, and Intelligence Systems, Data Delivery

USING COMMERCIAL OFF-THE-SHELF DIGITAL SIGNAL PROCESSORS FOR RELIABLE SPACE BASED DIGITAL SIGNAL PROCESSING

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A radiation tolerant testbed was designed using a Commercial-off-the-Shelf (COTS) Digital Signal Processor (DSP) and presented to prove the concept of Triple Modular Redundant (TMR) processors in order to make a COTS DSP radiation tolerant design. The system was designed to handle the effects of radiation associated with Single Event Upset only.

Two of the industry's leading programmable 32-bit floating-point digital signal processors were reviewed for this thesis, Analog Devices ADSP-21060 and the Texas Instruments TMS320C6701. The '6701 was the best processor for this design based upon size, power, speed, and tolerance to single event latchup, signal event burnout, and total ionization dose. A review of the processor's performance and characteristics is provided to ensure the proper operation of '6701 in a TMR design.

The system employs a bit by bit voter that compares the three processors' results and outputs the majority of the bits. All data, address, and control signals are monitored to determine that the system is operating properly. This system significantly differs from previous TMR designs, because only address errors cause immediate interrupts. Data errors cause processor interrupts only when the errors accumulate to a critical level. An external host processor controls the processors' shared memory space.

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Electronics, Computing and Software

KEYWORDS: Fault-tolerant Computing, Digital Signal Processors, Texas Instruments TMS320C6701, Commercial-off-the-Shelf Technology, Radiation, Triple Modular Redundant, Analog Devices ADSP-21060

ANALYSIS OF A MAGNETIC THREE-AXIS STABILIZED ATTITUDE CONTROL SYSTEM FOR THE NPSAT1 SPACECRAFT

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The NPSAT1 satellite uses an active magnetic torque rod system, with a magnetometer for attitude determination, to maintain 3-axis stabilization, with a slightly gravity gradient friendly structure.

This thesis will examine the performance of three combinations of programs and simulation models for the NPSAT1 satellite attitude control system. The models include a magnetic control law with a reduced order estimator to generate torque commands to achieve spacecraft nadir pointing and a magnetic rate (Bdot) control law to reduce spacecraft angular rates. The performances of two Bdot mode switching designs are compared. Also, a case is made for the benefits of priming the system's reduced estimator prior to mode switching.

All of the control methods analyzed appear to be valid control methods to achieve three-axis attitude stabilization using only magnetic torquers for active control. The most efficient control method analyzed incorporates a hand-off method from a magnetic rate (Bdot) control loop to a magnetic control loop. The results of this analysis indicates that the best use of this method is to perform the Bdot hand-off following the achievement of a predetermined combined angular rate.

DoD KEY TECHNOLOGY AREAS: Space Vehicles

KEYWORDS: NPSAT1, Attitude Control System, Three-Axis Attitude Stabilization

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